भारत सरकार के प्रधान वैज्ञानिक सलाहकार का कार्यालय
Office of the Principal Scientific Adviser
to the Government of India

Fire Safety in Charge Parks for Medium and Heavy-Duty Electric Trucks and Buses in India





November 2026

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भारत सरकार के प्रमुख वैज्ञानिक सलाहकार
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FOREWORD

India is witnessing a significant transformation in its road freight and public transportation sectors, with the increasing adoption of electric trucks and buses. The transition towards Zero Emission Trucks (ZETs) is an important component of India's efforts towards reducing emissions, enhancing energy security and developing a cleaner and more sustainable transportation ecosystem. The Office of PSA has been consistently supporting the development of technical and policy pathways for accelerating ZET adoption in India. The current report on **"Fire Safety in Charge Parks for Medium and Heavy-Duty Electric Trucks and Buses in India."** is a logical extension of previous policy documents, technical studies and reports.

As the deployment of ZET expands, the development of reliable, safe and accessible high-power charging infrastructure will be essential for supporting this transition. Charge Parks for medium- and heavy-duty electric trucks and buses represent a new category of critical infrastructure. Unlike conventional vehicle fuelling or parking facilities, these facilities bring together high-voltage electrical systems, high-power charging equipment, large traction batteries, and large Battery Energy Storage Systems (BESS) within a common environment. This combination creates a distinct set of fire and safety considerations that require systematic attention.

The present report provides a comprehensive framework covering fire hazards and their causes, site planning and zoning, electrical and EVSE safety, BESS-specific safeguards, fire detection and suppression systems, emergency response,

post-incident management, training and competency requirements, and operational checklists and procedures. The recommendations draw upon relevant Indian regulations and standards as well as established practices from electrical substations, fuel retail facilities and BESS installations.

An important principle underpinning this report is that fire safety must be approached as an integral part of systems engineering, rather than viewed merely as a standalone compliance requirement. Accordingly, the report provides a risk-informed framework to guide the planning, design, construction and operation of electric truck and bus charging facilities.

I hope that this report will serve as a useful reference for policymakers, Charge Park developers and operators, fleet operators, utilities, fire and emergency services, urban planners, regulatory authorities, technology providers and other stakeholders involved in the development of electric truck and bus charging infrastructure in India.

I would like to extend my sincere appreciation for the valuable contributions, expertise and efforts of all the experts, institutions and stakeholders who have been associated with the preparation of this report.

[Ajay Kumar Sood]

New Delhi
03.11.2026

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MESSAGE

The shift towards zero-emission transport through the electrification of heavy-duty vehicles offers a significant opportunity to advance freight sector decarbonisation, strengthen energy security and promote sustainable economic growth. Therefore, PSA office, with its ongoing work of the Consultative Group on e-Mobility (CGeM) and the Centre of Excellence for Zero Emission Trucking (CoEZET) is consistently releasing policy documents, supporting several technical studies, and releasing technical reports to facilitate electrification of heavy-duty vehicles in India.

The successful deployment of electric trucks and buses would not only require suitable vehicles and charging infrastructure, but also a robust safety framework for the associated charging ecosystem. The Charge Parks bring together high-voltage electrical equipment, high-power charging systems, large-capacity batteries, battery energy storage systems, communication and control systems, and heavy vehicles in a relatively concentrated area. Consequently, fire prevention, early detection, containment and emergency response need to be incorporated into the design and operation of such facilities from the outset. The present report on **"Fire Safety in Charge Parks for Medium and Heavy-Duty Electric Trucks and Buses in India"** provides a structured technical framework covering the complete safety of a Charge Park.

The report examines potential hazards associated with all subsystems, structural arrangements, environmental conditions and human factors and provides guidance on preventive and protective measures, fire detection and alarm systems, suppression approaches, emergency management, training and competency, and standard operating procedures. An important principle highlighted in this report is that fire safety needs to be addressed as an integrated systems-engineering consideration rather than as an isolated compliance requirement.

I trust that this report will serve as a useful reference for policymakers, infrastructure developers, charge point operators, fleet operators, utilities, fire services, technology providers and other stakeholders involved in planning, approving, designing, operating and maintaining Charge Parks in India.

I extend my appreciation to all members of the Consultative Group on e-Mobility, experts, contributors and stakeholders whose valuable inputs and efforts have supported the preparation of this report. I trust that this document will serve as a practical reference for establishing a robust and consistent fire-safety framework for Charge Parks across India.

Maini

(Parvinder Maini)

Dated : 03rd November, 2026

Table of Contents

List of Figures 7

List of Tables 8

Abbreviations 9

Executive Summary 10

Chapter 1 · Introduction and Context 13

1.1 Policy Drivers for Zero-Emission Trucking in India 13

1.2 Role of Charge Parks in Medium- and Heavy-Duty Truck Electrification 14

1.3 Overview of the Fire Risk Landscape in Charge Parks 14

1.4 Reference Facilities and Lessons for Charge Parks 15

Chapter 2 · Heavy-Duty Electric Truck Charge Park: Functional Description 17

2.1 Design Basis and Capacity Assumptions 17

2.2 Major Electrical Equipment and System Schematic 17

2.3 Physical Layout and Zoning 18

2.4 Example Equipment List (Major Items) 19

2.5 Block Diagram of an Electric Truck or Bus Charge Park 20

Chapter 3 · Fire Hazards and Causes in Truck Charge Parks 22

3.1 Electrical Hazards (High Voltage and Low Voltage) 22

3.2 EVSE and Connector Hazards 22

3.3 Stationary BESS Hazards 22

3.4 Vehicle Battery Hazards (Traction Packs) 22

3.5 Parking, Structural, and Environmental Hazards 23

3.6 Human and Operational Hazards 23

Chapter 4 · Mandatory and Optional Safety Controls 24

4.1 Site Selection and Macro-Siting Controls 24

4.2 Layout, Compartmentation, and Minimum Separation Distances 24

4.3 Civil and Structural Controls 26

4.4 Electrical Design and Installation Controls 28

4.5 EVSE Design and Installation Controls 29

4.6 BESS-Specific Controls 29

4.7 Markings, Signage, and Information Systems 29

Chapter 5 · Fire Detection, Alarm, and Suppression Systems 31

5.1 Detection Technologies and Zoning 31

5.2 Fixed Suppression for Electrical and Structural Fires 31

5.3 Specialised Approaches for EV and BESS Fires 32

5.4 Utilities and Water Supply Planning 34

5.5 Interface with First Responders and External Agencies 34

Chapter 6 · Emergency Management 35

6.1 Emergency Response Plans 35

6.2 Fire Rescue Techniques for the Charger 36

6.3 Post-Incident Management 36

6.4 Fire Rescue Techniques for Electric Trucks 37

Chapter 7 · Roles, Training, and Skilling Requirements 38

7.1 Competency and Training Matrix 38

7.2 Frequency and Assessment 38

Chapter 8 · Checklists, Do's and Don'ts, and Model SOPs 39

8.1 Design and Approval Phase Checklist (Indicative) 39

8.2 Do's and Don'ts 39

8.3 SOP Concepts for Key Scenarios 40

8.4 First Aid Procedure 41

References 42

Appendix 1 · Major Zero-Emission Trucks Currently Operating in India 43

Appendix 2 · Indicative List of Manufacturers / Suppliers 45

Appendix 3 · Fire Order Site Poster 47

Acknowledgements 49

List of Figures

Figure 1. Factors influencing Fires at Charge Parks… 15
Figure 2. Block diagram of electric truck or bus charge park… 20
Figure 3. Typical Electric Truck or Bus Charge Park with various Charger technologies… 21
Figure 4. A national-highway EV charging hub with fire protection boards installed between adjacent truck charging bays… 27
Figure 5. Various safety signs for Charging infrastructure… 30
Figure 6. Various Fire detection systems in Charging infrastructure… 31
Figure 7. Four classes of fixed fire-suppression systems used in DC charging infrastructures 32
Figure 8. Hydrants Requirement in DC Charging infrastructure for Electric Trucks or Buses. 33
Figure 9. Fire Blankets to be used in an Electric Vehicle DC Charging infrastructure… 34
Figure 10. Fire incident procedure for site staff, electric-truck drivers, and visitors… 35
Figure 11. Fire rescue sequence for a charging station involving an electric truck or bus… 36
Figure 12. Post-incident safety priorities… 36
Figure 13. Fire rescue of a parked or charging electric truck involving a battery-pack fire… 37
Figure 14. First aid for electric-truck charging-station fire hazards… 41
Figure 15. Fire order: prevention, protection, and extinguishment – Site Poster… 47

List of Tables

Table 1. Critical design distances..... 26
Table 2. Fire-resistance rating by board thickness (Integrity, Insulation, and Stability/load-bearing)..... 28
Table 3. Fire extinguisher selection for DC charging infrastructure..... 33
Table 4. Site planning and safety — Do's and Don'ts..... 39
Table 5. EV user etiquette (at public charging stations) — Do's and Don'ts..... 40
Table A1. List of major zero emission trucks available in India..... 43

Abbreviations

Abbreviation	Full Form	Abbreviation	Full Form
AAC	Autoclaved Aerated Concrete	Li-ion	Lithium-ion
AC	Alternating Current	LOTO	Lock-Out/Tag-Out
ACC	Advanced Chemistry Cell	LPG	Liquefied Petroleum Gas
AVD	Aqueous Vermiculite Dispersion	LV	Low Voltage
BESS	Battery Energy Storage System	MCB	Miniature Circuit Breaker
BIS	Bureau of Indian Standards	MCCB	Molded Case Circuit Breaker
BMS	Battery Management System	MCS	Megawatt Charging Systems
CAN	Controller Area Network	MD	Medium Duty
CCS	Combined Charging System	MoHUA	Ministry of Housing and Urban Affairs
CCTV	Closed-Circuit Television	MoP	Ministry of Power
CEA	Central Electricity Authority	NBC	National Building Code of India
CoEZET	Centre of Excellence for Zero Emission Trucking	NFPA	National Fire Protection Association
DC	Direct Current	NMC	Nickel Manganese Cobalt
DCP	Dry Chemical Powder	NOC	No Objection Certificate
DG	Diesel Generator	OCPP	Open Charge Point Protocol
DISCOM	Distribution Company	OEM	Original Equipment Manufacturer
EMI	Electromagnetic Interference	O&M	Operation and Maintenance
EPO	Emergency Power-Off	OPSA	Office of the Principal Scientific Adviser
EV	Electric Vehicle	PLC	Power-Line Communication
EVSE	Electric Vehicle Supply Equipment	PLI	Production Linked Incentive
FAME	Faster Adoption and Manufacturing of (Hybrid and) Electric Vehicles	PNGRB	Petroleum and Natural Gas Regulatory Board
FRR	Fire Resistance Rating	PPE	Personal Protective Equipment
GST	Goods and Services Tax	PSA	Principal Scientific Adviser
GVW	Gross Vehicle Weight	PU	Polyurethane
HD	Heavy Duty	RCC	Reinforced Cement Concrete
HMS	Hydrated Mica Suspension	RCD	Residual Current Device
HT	High Tension	RMU	Ring Main Unit
HV	High Voltage	SCADA	Supervisory Control and Data Acquisition
HVAC	Heating, Ventilation and Air-Conditioning	SFRM	Spray-Applied Fire-Resistive Material
IEC	International Electrotechnical Commission	SOP	Standard Operating Procedure
IMD	Insulation Monitoring Device	UPS	Uninterruptible Power Supply
LFP	Lithium Iron Phosphate	ZET	Zero-Emission Truck

Executive Summary

India is at a critical juncture in transforming its freight mobility sector. As the country aims to transition towards a developed and low-carbon economy, accelerated electrification of medium- and heavy-duty trucks and buses becomes a strategic priority. Realising this transition at scale requires not only advances in vehicle technologies and charging infrastructure, but also robust measures to ensure safety, reliability and public confidence. Going forward, **Charge Parks**, integrating high-voltage electrical systems, high-power charging equipment, large-capacity lithium-ion batteries, energy storage, digital control networks and intensive vehicle operations, will form a new category of critical infrastructure. Therefore, their safety and reliability become essential to enabling the widespread adoption of electric freight mobility in India.

This convergence of technologies creates unprecedented opportunities for sustainable transportation but also introduces a complex fire-risk environment that differs significantly from conventional fuel stations, logistics parks, truck terminals, and electrical substations. Fire events involving lithium-ion batteries are fundamentally different from conventional fuel fires. They can generate extreme temperatures, toxic gases, explosive atmospheres, prolonged burn durations, thermal runaway propagation, and delayed re-ignition even after apparent extinguishment. Consequently, traditional fire-protection approaches alone are insufficient.

This report has been developed to provide a comprehensive technical framework for ensuring fire-safe design, construction, operation, maintenance, and emergency management of Charge Parks serving medium- and heavy-duty electric trucks and buses in India. It seeks to support policymakers, infrastructure developers, fleet operators, charging-point operators, utilities, urban planners, fire services, regulatory authorities, and technology providers in establishing a common safety baseline for this rapidly emerging sector.

The report recognises that fire safety in Charge Parks must be approached as an integrated systems-engineering challenge. A Charge Park is not merely a collection of charging points; it is a complex ecosystem comprising grid connections, transformers, switchgear, power conversion systems, charging equipment, Battery Energy Storage Systems (BESS), communication networks, truck parking areas, operational facilities, and human operators. Failure in any one element can interact with others and escalate rapidly unless appropriate safeguards are in place. Therefore, the report adopts a holistic philosophy that combines prevention, detection, isolation, containment, suppression, emergency response, and post-incident management into a single safety framework.

The guidance contained in this report is derived from Indian regulatory requirements and international best practices. It draws upon provisions from the Central Electricity Authority (CEA), National Building Code of India (NBC), Bureau of Indian Standards (BIS), Ministry of Power guidelines, state fire regulations, and globally recognised frameworks such as National Fire Protection Association (NFPA) standard NFPA 855 governing stationary energy storage systems. Equally important, it incorporates practical lessons from infrastructure sectors that have managed high-energy hazards for decades, including electrical substations, fuel retail facilities, logistics yards, parking structures, and BESS installations.

A key conclusion of this report is that **proper site planning and appropriate physical separation between its constituents is the most effective and economical means of reducing fire risk**. Adequate separation distances between trucks, charging equipment, transformers, BESS containers, buildings, and hazardous installations significantly reduce the likelihood of fire propagation. Fire-resistant walls, compartmentation systems, dedicated hazard zones, controlled access areas, and protected cable routes act as passive safeguards that remain effective even in the event of equipment failure, human error, or loss of electrical power. These passive measures form the foundation upon which all active fire-protection systems must be built. Overall, a well-designed Charge Park must have physical barriers that prevent a localised incident from becoming a catastrophic multi-vehicle event.

The report further highlights that the largest emerging fire challenge in electric truck infrastructure arises from lithium-ion battery systems. Both traction batteries installed in vehicles and stationary Battery Energy Storage Systems possess extremely high energy densities. While modern battery systems incorporate multiple layers of protection, incidents involving thermal runaway can result in rapid heat release, toxic and flammable gas generation, high-temperature jet flames, and prolonged cooling requirements. Unlike conventional hydrocarbon fires, lithium-ion battery fires often cannot be fully extinguished using traditional firefighting methods. In this case, the most effective response strategy focuses on cooling, containment, isolation, and prevention of propagation. The report therefore emphasises the need for specialised suppression systems, high-capacity water supplies, thermal monitoring, gas detection, emergency isolation procedures, and post-incident surveillance to mitigate re-ignition risks.

Another important finding is that **early detection and rapid electrical isolation are decisive factors in preventing escalation**. Modern Charge Parks should employ multiple layers of detection technologies, including smoke, heat, flame, gas, and thermal imaging systems, integrated with intelligent control platforms capable of initiating alarms, equipment shutdowns, and emergency actions within seconds. Emergency Power-Off (EPO) systems, coordinated protection schemes, insulation-monitoring devices, arc-fault detection systems, and remote monitoring capabilities are essential for converting potentially serious incidents into manageable events. The report therefore advocates a transition from conventional reactive response to a fire incidence towards predictive and digitally enabled fire safety and fire risk management.

The study also identifies Battery Energy Storage Systems as a distinct hazard category requiring dedicated treatment. BESS installations should never be viewed simply as electrical equipment. They represent concentrated energy assets that demand independent zoning, engineered ventilation, explosion mitigation, gas monitoring, separation distances, emergency planning, and specialised firefighting approaches. Their design philosophy should prioritise containment and resilience such that a failure within a single container or module does not cascade to neighbouring infrastructure or occupied areas.

A recurring theme throughout the report is the central role of human oversight in fire risk management. Even the most advanced technological safeguards can be undermined by inadequate maintenance, poor operational discipline, improper modifications, insufficient training, or delayed decision-making during emergencies. Accordingly, the report recommends the establishment of robust competency frameworks, periodic training programmes, emergency drills, standard operating procedures, and certification mechanisms for personnel involved in Charge Park design, operation, maintenance, inspection, and emergency response. Safety culture must evolve alongside technology deployment to ensure sustainable and safe growth of the sector.

The report further emphasises that emergency preparedness must extend beyond firefighting. Effective response requires coordination among Charge Park operators, local fire services, utilities, police authorities, emergency medical services, fleet operators, and regulatory agencies. Clear communication channels, predefined allocations of responsibilities, standard operating procedures, incident command structures, evacuation procedures, and mutual-aid arrangements are essential to manage complex incidents involving heavy-duty electric vehicles and high-energy electrical systems. Post-incident activities, including monitoring for re-ignition, environmental management of contaminated runoff, technical investigations, equipment recertification, post-event reporting and lessons-learned reviews, are equally important components of the overall safety lifecycle.

This report therefore proposes a comprehensive framework built on six mutually reinforcing pillars:

1. **Prevention through safe planning, engineering, and design.**
2. **Protection through fire-resistant construction, compartmentation, and safety systems.**
3. **Detection through intelligent monitoring and early-warning technologies.**

4. **Response through rapid isolation, suppression, and emergency management.**
5. **Recovery through structured post-incident assessment and restoration.**
6. **Resilience through training, governance, and continuous improvement.**

Ultimately, fire safety must be regarded not as a compliance requirement, but as a strategic enabler of India's electric freight transition. Public confidence in zero-emission trucking will depend upon the industry's ability to demonstrate that high-power charging infrastructure can be deployed with safety standards comparable to, or exceeding, those of conventional energy infrastructure. The recommendations presented in this report are intended to support that objective by establishing a robust, science-based, and risk-informed foundation for Charge Park development across India.

As India builds the next generation of freight infrastructure, Charge Parks will become critical nodes in the nation's transport and energy ecosystems. Ensuring their safe and reliable operation will be essential for the sustainable growth of electric freight mobility. The adoption of the principles, engineering controls, operational practices, and emergency-management procedures described in this report will contribute significantly to protecting human life, safeguarding public assets, enhancing infrastructure reliability, enabling investor confidence, and accelerating the transition towards a cleaner, safer, and more sustainable freight transportation future for India.

Chapter 1 · Introduction and Context

1.1 Policy Drivers for Zero-Emission Trucking in India

India's transition to zero-emission trucking (ZET) has moved from exploratory pilots to structured, industrially-scaled deployments. Trucks account for only about 3% of registered vehicles yet contribute ~40% of India's road-transport CO_2 emissions, making the segment very important to the country's "Viksit Bharat 2047" vision and its 2070 net-zero commitment. Government policy now targets to bridge this gap through a multi-layered framework of financial incentives, domestic manufacturing support, and corridor-based charging infrastructure for wider adoption of ZET in India.

Financial and regulatory incentives

- **Direct subsidies:** The PM E-DRIVE (Electric Drive Revolution in Innovative Vehicle Enhancement) scheme, a successor to the FAME-II Scheme of Ministry of Heavy Industries, earmarks a dedicated outlay of ₹500 crore for electric trucks, with incentives of ₹5,000 per kWh of battery capacity, or 10% of ex-factory price (up to ₹1.25 crore for heavy-duty N3 vehicles) or a GVW-linked ceiling of up to ₹9.6 lakh per vehicle whichever is lowest.
- **Scrappage linkage:** Subsidy disbursement requires a Certificate of Deposit from a registered vehicle-scrapping facility, tying fleet modernisation to genuine emission reduction rather than fleet expansion.
- **Tax benefits:** Electric trucks attract a preferential 5% GST rate, against 18% for internal-combustion-engine counterparts, substantially narrowing the total-cost-of-ownership gap.

Supply-side and manufacturing drivers

- **Phased Manufacturing Programme:** Mandates effective 1 September 2026 require domestic manufacture of traction motors, rotors, and stator assemblies for all subsidy-eligible trucks.
- **PLI Scheme for Advanced Chemistry Cell (ACC) storage.** Now reaching peak output, this scheme targets the battery pack, the single largest cost component of an electric truck, through localised cell production.

Infrastructure and strategic frameworks

- The e-FAST India (Electric Freight Accelerator for Sustainable Transport) platform, led by NITI Aayog, coordinates OEMs, logistics operators, and policymakers.
- **Priority corridors:** Ten high-traffic freight corridors have been identified for phased deployment of high-power and megawatt-scale charging stations.
- **The Bharat Zero-Emission Trucking Policy Advisory** released by the Office of the Principal Scientific Adviser (OPSA) to the Government of India on 21 August 2024 recommends interoperable, India-centric charging standards, including a dual-gun plug-in concept designed to reduce charging downtime for heavy-duty long-haul operations.

NITI Aayog's 2026 "Transport Sector Insights" report estimates that achieving 30% zero-emission-vehicle penetration by 2030 will require roughly US$4.3 trillion of investment over the long term; near-term policy is focused on de-risking the early-adopter phase by subsidising approximately 5,600 e-trucks through 2026 to demonstrate commercial viability to large fleet operators.

1.2 Role of Charge Parks in Medium- and Heavy-Duty Truck Electrification

Why dedicated infrastructure is critical

- **Operational viability:** High-capacity charging (150 kW to 1 MW) must match the 38–44-minute breaks (dwell times) drivers already take, so that electrification does not disrupt tight logistics schedules.
- **Range confidence:** Stations placed along Golden Quadrilateral corridors and major freight hubs reduce the need for oversized battery packs that would otherwise be needed for 500 km+ range.
- **Total cost of ownership:** Managed depot charging during off-peak hours (11 p.m.–6 a.m.) allows fleet operators to leverage lower time-of-day tariffs, a key lever in making electric trucks cost-competitive against diesel.

Current Infrastructure landscape and government push

- **Network targets:** PM E-DRIVE scheme funds 1,800 dedicated charging stations for buses and trucks on national highways.
- **Standardisation:** The sector is converging on the CCS 2 connector standard, with Megawatt Charging Systems (MCS) under evaluation to support the 1,000 V architectures of newer heavy-duty trucks.
- **Policy support:** Revised 2024–2026 guidelines mandate fast-charging stations at least every 100 km on highways for heavy-duty EVs, backed by subsidised land and open access to green energy.

Key challenges and outlook

- **Grid capacity:** A single 1 MW charger requires a service upgrade comparable to a small factory; coordination with DISCOMs for these high-power connections remains a bottleneck.
- **Depot-centric model:** Industry forecasts suggest roughly 80% of truck charging will occur at private depots, with public en-route charging serving mainly as a range-extender.
- **Land and logistics:** Heavy trucks need substantially more manoeuvring space (approximately 300 m^2 per station) than passenger cars, necessitating specialized, electric truck-only charging hubs.

1.3 Overview of the Fire Risk Landscape in Charge Parks

Charge parks are specialised, high-power hubs supporting electric trucks and buses. Introduced without careful management, the charging equipment they contain can become an ignition hazard within the workplace or in public areas such as highways, service stations and parking yards. The principal potential sources of fire identified for this study are given below (*see* Figure 1):

- Battery leakage, damage, or internal short circuit — in either the vehicle traction pack or a stationary BESS.
- Ageing, faulty, or improperly maintained electrical equipment, like AC/DC and DC/DC converters.
- Loose electrical connections occurring during charging.
- Overheating of switchgear and transformers in hot-weather conditions.
- Natural causes, principally lightning strikes and thunderstorms.
- Vehicle collision with a charger, potentially triggering battery thermal runaway.
- Sparks arising from incoming power overload or short-circuit faults in charging cables.

- Auto-ignition of flammable materials such as electrolytes and other liquid or gaseous fuels.
- Leakage of mineral oil from oil-filled distribution transformers.
- Electrical arcing arising from liquid-cooling-system degradation or connector and insulation damage.
- Failure of communication protocols, including faults in the Open Charge Point Protocol (OCPP).
- Charger-gun failure caused by moisture ingress or exposure to water.

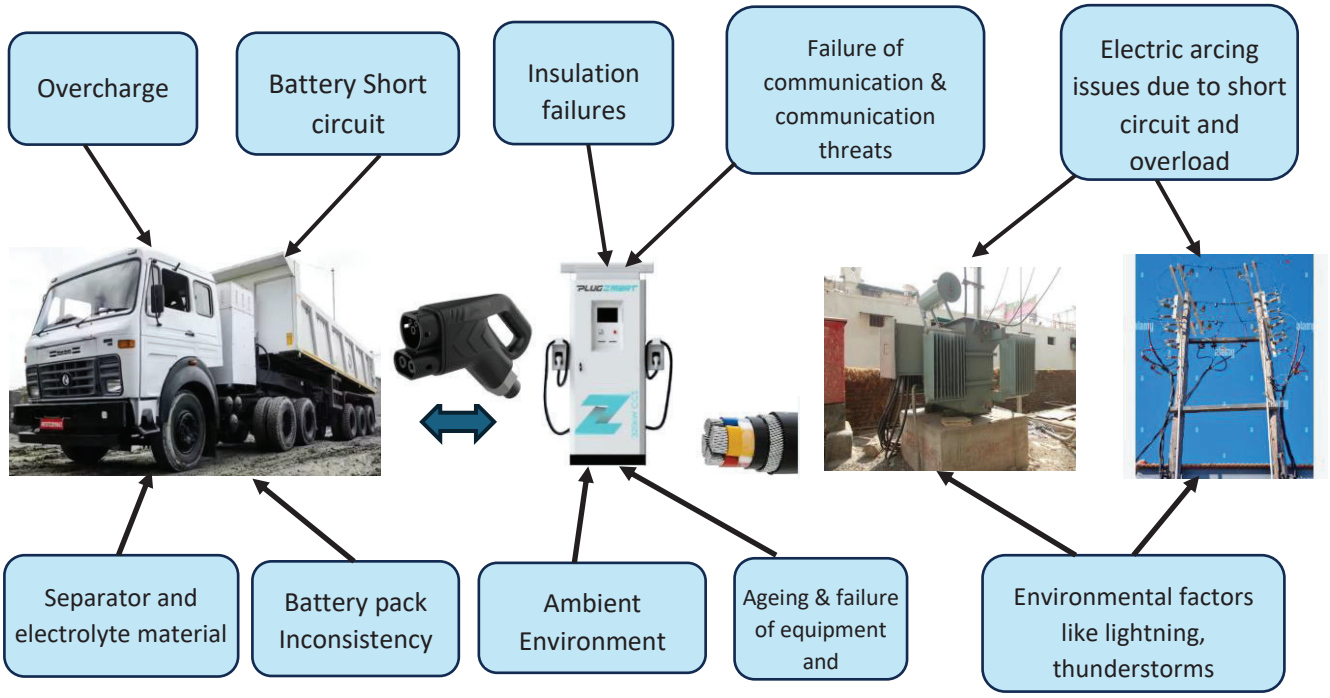


Figure 1. *Factors influencing Fires at Charge Parks*

Because these hazards span electrical plant, stationary and vehicle batteries, and human factors simultaneously, the remainder of this report treats fire safety as a single, integrated system rather than a checklist of isolated equipment requirements.

1.4 Reference Facilities and Lessons for Charge Parks

The guidance for this report was derived from operating lessons drawn from four reference facility types that already manage comparable hazards in India: 11 kV electrical substations, fuel retail outlets, parking structures and truck yards, and BESS installations.

Electrical Substations (11 kV and above)

Indian 11 kV distribution substations and packaged substations follow CEA “Measures relating to Safety and Electric Supply” Regulations and technical standards for construction of electrical plants and lines, with detailed provisions on clearances, earthing, fencing, and fire separation. Indoor 11 kV layouts typically segregate HV switchgear, transformers, Low voltage distribution, and control rooms, with fire-rated walls and minimum clearances between oil-filled equipment and structures.

Lessons for charge parks:

- Adequate phase-to-phase and phase-to-earth clearances and creepage distances; use of metal-clad, enclosed switchgear and transformer fire separation.
- Robust earthing grid and bonding as per IS 3043 to control touch and step voltages and ensure fast fault clearance by protection devices.
- Dedicated cable trenches with fire-resistant covers, segregation of control and power cables, and routing away from combustible materials and public areas.

Fuel Retail Outlets and Gas Stations

Oil & Gas retail outlets are governed by Petroleum and Natural Gas Regulatory Board (PNGRB) safety standards and state fire authority norms, which emphasize hazardous area classification, minimum separation distances, and strict control of ignition sources. EV charging installed inside fuel stations is required to maintain separation from LPG/fuel storage (typically 15 m) and avoid placement near combustible stock or hazardous installations.

Lessons for charge parks:

- Zoning of hazardous areas, controlled access, and clear demarcation of fuelling/charging bays versus circulation roads.
- Provision of appropriate fire extinguishers, sand buckets, and emergency shutdown systems, with trained operators at all times.

Parking Structures and Truck Yards

State fire authorities (for example, Maharashtra Fire Services) have issued parking fire safety guidelines, including specific provisions for EVs and bans on EV charging in enclosed automated or basement parking towers due to uncontrolled fire spread risk. Parking guidelines stress minimum marginal open spaces around plots for fire appliance manoeuvring and caution that vehicles located with very close horizontal and vertical spacing result in rapid fire spread due to high fuel load.

Lessons for charge parks:

- Maintain sufficient spacing and fire compartmentation between vehicle groups, avoid deep stacks of vehicles with no separation, and ensure access routes for fire engines around parking and charging areas.
- Avoid EV charging in closed or poorly ventilated spaces; charging for large traction batteries should be in open or well-ventilated canopies with adequate smoke and heat venting.

Battery Energy Storage System (BESS) Installations

Internationally, NFPA 855 governs installation of stationary energy storage systems, with requirements on spacing, fire containment, gas venting, and emergency planning. Engineering practice documents for BESS stress the centrality of thermal runaway risk, gas generation and explosion potential, re-ignition hazards, and the need for fire-resistant barriers and minimum 6 m spacing between containerized BESS units unless alternative measures are implemented.

Lessons for charge parks:

- Treat BESS as a distinct hazard zone with defined separation from buildings, transformers, and vehicle parking, and provide engineered ventilation and explosion relief.
- Design for controlled burn and containment, rather than assuming full extinguishment, and prepare detailed emergency response and monitoring protocols for post-fire re-ignition.

Chapter 2 · Heavy-Duty Electric Truck Charge Park: Functional Description

2.1 Design Basis and Capacity Assumptions

For the purposes of this report, a representative heavy-duty electric-truck charge park in India is assumed to comprise the following:

- Incoming three-phase grid supply at 11 kV or higher (such as 33 kV), stepped down to low voltage (typically 415–690 V) through one or more transformers.
- At least five DC fast chargers, each rated 240 kW or higher and capable of dual-gun operation, enabling simultaneous charging of at least five trucks with diversity in load factor.
- Parking capacity for at least five additional trucks that are waiting or resting, physically segregated from active charging bays but within the same premises.
- An optional on-site BESS (typically 1–5 MWh) to manage peak demand, integrate renewables, and provide resilience; the BESS may be AC- or DC-coupled.
- Ancillary buildings and amenities: a control room, office, crew facilities (toilets, rest area, food/refreshments), a security cabin, possibly a small workshop, and utility rooms for the DG set, pump house, and water tank.

2.2 Major Electrical Equipment and System Schematic

A representative single-line concept for an 11 kV-fed heavy-truck charge park includes the following elements:

Utility interface and 11 kV switchgear

- An outdoor or indoor Ring Main Unit (RMU) / 11 kV vacuum-circuit-breaker panel, with an incoming utility feeder and outgoing feeders to transformers and any dedicated BESS or auxiliary loads.
- A metering cubicle and protection relays compliant with CEA regulations.

Transformers

- One or more transformers (for example, 11/0.4 kV, 2–5 MVA total capacity depending on simultaneous-load assumptions) feeding low-voltage power distribution boards.
- Oil-free (dry-type or cast-resin) transformers are preferred for reduced fire risk; where oil-filled transformers are used, they must have firewalls, oil containment, and separation distances as per NBC and CEA norms.

Low-voltage distribution

- A main LV power distribution board with an incoming air/moulded-case circuit breaker, and outgoing feeders to charger groups, the BESS power-conversion system (if AC-coupled), auxiliary services (lighting, HVAC, buildings), and emergency systems.
- Sub-distribution boards within charging zones, sized for the number and rating of chargers, with protective devices such as MCBs/MCCBs, residual current devices, surge protection devices, and arc-fault detection devices, coordinated with charger requirements.

DC fast chargers (EVSE)

- High-power DC fast chargers compliant with IS 17017 Part 23/Part 30 for 50–250+ kW Class III/IV DC charging, using CCS or other specified connectors.
- Dual-gun configuration per charger to serve two vehicles, with dynamic load-sharing between outputs.
- **Integrated protections**: overcurrent, overvoltage, residual current, insulation monitoring, emergency stop, ground-fault detection, and vehicle communications via ISO/IS 15118 (power-line communication (PLC)) or CAN.

Cabling and trenches

- 11 kV cables routed from the RMU to transformers laid in dedicated trenches or cable ducts, with proper segregation and marking.
- LV feeders from transformers/distribution boards to chargers via buried cable trenches or overhead cable trays, with mechanical protection and fire-resistant properties where required.
- Earthing and bonding conductors integrated with the overall earthing grid.
- For DC fast chargers drawing more than 150 A current, liquid-cooled cables (for example, water-glycol mixtures, or dimethyl silicone oil and synthetic esters) with a coolant pump, temperature sensors, heat exchanger, and coolant reservoir.

On-site BESS (if provided)

- Containerised or modular BESS units with a power-conversion system, battery racks, HVAC, and a battery management system, located in a dedicated BESS yard separated from transformers, buildings, and vehicle areas.
- This is used to smooth peak loads and to reduce peak demand charges. This stores solar energy and improves reliability during grid fluctuations.
- Integration either AC-coupled to the LV bus via dedicated feeders, or DC-coupled where chargers are fed from a common DC bus, as explored in high-power DC-hub designs.

Auxiliary systems

- Lighting, CCTV, access control, a public-address system, an ICT backbone, and SCADA/BMS for monitoring and control of chargers, the BESS, and electrical equipment.
- A fire detection and alarm control panel, hydrant system, water tank and pump house, emergency diesel generator (if required), and UPS for critical loads.

2.3 Physical Layout and Zoning

Charge-park site geometries vary, but a typical charge-park layout can be organised into five functional zones.

Electrical yard

- Located at one corner or edge of the plot with controlled access (fencing, gates) and clear separation from public and vehicle zones.

- Houses the 11 kV RMU/switchgear, transformers, LV switch-room, BESS yard, DG set, and main LV distribution, with fire-rated walls and doors separating rooms per NBC Part 4 and local fire bye-laws.

Charging bays

- A linear arrangement of at least five heavy-duty electric truck charging bays, each capable of accommodating long combination vehicles, with drive-through or angled parking for easy ingress and egress.
- DC chargers located on islands or behind protective bollards between bays, with cable-management systems keeping cables off the ground and within safe bending radii.

Truck parking / staging area

- Separate from charging bays, providing at least five additional truck slots for waiting or resting, with greater spacing than typical car parks to reduce fire spread and allow manoeuvring of fire appliances.
- No charging permitted in this zone except possibly low-power auxiliary loads in clearly marked areas.

Crew amenities and Ancillary buildings

- Low-rise, non-combustible structures housing the control room, office, restrooms, showers, a rest lounge, security cabin, utility rooms (DG set, pump house and water tank) and a small cafeteria, placed outside high-hazard electrical/BESS zones with safe egress paths.
- Separated from charging bays and the BESS by minimum distances and, where necessary, fire walls.

Circulation and emergency access

- Internal roads designed for truck turning radii that also accommodate fire tenders, with minimum marginal open spaces around the plot to enable access for fire and rescue vehicles
- Clearly marked emergency assembly points and access to hydrants and water sources.

2.4 Example Equipment List (Major Items)

A non-exhaustive list of major equipment for a heavy-duty electric vehicle charge park would include:

- 11 kV RMU or switchboard with incoming and outgoing feeders.
- 11/0.4 kV or 11/0.69 kV transformers (dry-type preferred).
- Main LV power distribution board and sub-distribution boards.
- DC fast chargers (≥240 kW, dual-gun) complying with the IS 17017 series and related communication standards.
- On-site BESS containers with power-conversion systems and battery management systems, where deployed.
- Fire detection and alarm system, fire hydrant network, yard hydrants/monitor nozzles, portable extinguishers, and, for critical rooms, water-mist or clean-agent systems.
- Earthing, lightning-protection system per IS 3043 and IS/IEC 62305 and thunderstorm arresters.
- Civil works such as foundations, cable trenches, transformer/fire walls, drainage, roadworks, and structural steel for canopies, etc.

2.5 Block Diagram of an Electric Truck or Bus Charge Park

The energy and control architecture of a typical charge park is represented in Figure 2 as a linear flow from grid or renewable energy supply, through protection and conversion, to the vehicle interface, with a parallel data path for monitoring, billing, and safety systems. A typical Electric Truck or Bus Charge Park with various Charger technologies is shown in Figure 3.

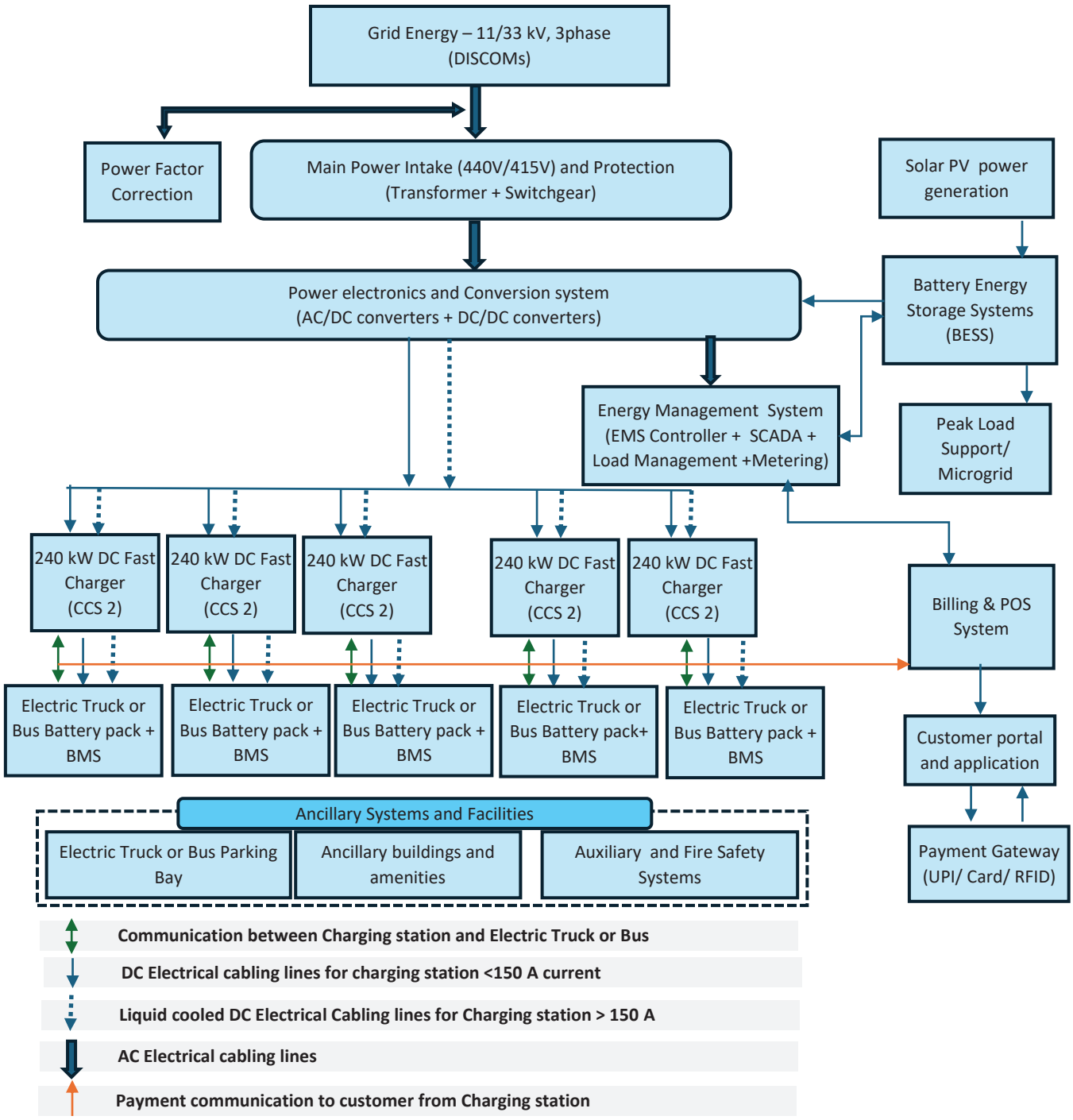


Figure 2. *Block diagram of electric truck or bus charge park*

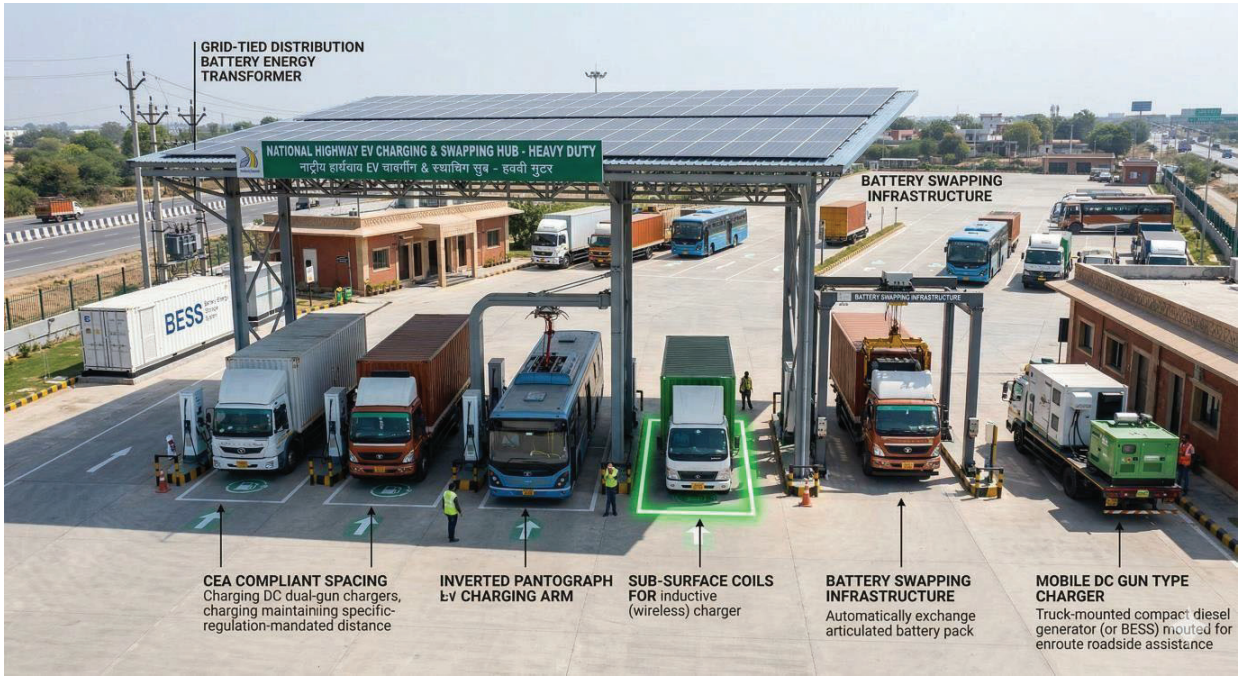


Figure 3. *Typical Electric Truck or Bus Charge Park with various Charger technologies*

A reference list of zero-emission trucks currently operating on Indian roads, with their dimensions, battery capacity, charging protocol, and range, is provided at **Appendix 1**.

Chapter 3 · Fire Hazards and Causes in Truck Charge Parks

3.1 Electrical Hazards (High Voltage and Low Voltage)

At the grid interface and within the electrical yard, the primary hazards are high-voltage faults (phase-to-phase or phase-to-earth), insulation failure, and equipment faults in switchgear and transformers, any of which can cause arcing, fire, or explosion if not properly contained. Poorly designed or overloaded low-voltage panels, inadequate clearances, improper terminations, and lack of maintenance can lead to overheating, insulation degradation and arc faults, particularly at the high load factors typical of DC fast charging.

Cable-related hazards include insufficient sizing, bundling of multiple high-current feeders without derating, inadequate mechanical protection, and water ingress which can cause local hotspots, insulation breakdown, and eventual fire along cable runs or at terminations. Inadequate earthing and bonding may produce dangerous touch voltages, stray currents, and higher fault energy, increasing the severity of any arc-flash or fire event.

3.2 EVSE and Connector Hazards

High-power DC chargers operate at currents of several hundred amperes per gun; any increase in connector contact resistance, due to wear, contamination, or improper mating, can cause severe localised heating. Damaged cables, poor strain relief, or kinking can compromise insulation and conductor integrity, leading to short circuits or arcing in close proximity to vehicles and personnel.

Water ingress from heavy rain, washing, or flooding into EVSE enclosures or connectors, where IP ratings and drainage are inadequate, can cause tracking, ground faults, and fire, particularly in combination with corrosion and poor maintenance. Cyber or control vulnerabilities, while not a direct ignition source, can lead to unsafe operating conditions such as failure of load management, disabled protections, or incorrect firmware which could result in overheating or overcharge if other safeguards also fail.

3.3 Stationary BESS Hazards

Lithium-ion BESS present a distinct hazard profile centred on thermal runaway, in which the failure of a single cell can propagate rapidly across modules and racks, releasing very high heat and flammable, toxic gases. Overcharging, internal defects, manufacturing faults, mechanical damage, or cooling-system failure can each initiate thermal runaway, while inadequate thermal management or fire barriers allow it to propagate.

Gas build-up within containers can lead to deflagration or explosion if not managed through appropriately designed vents and ventilation systems. NFPA 855 now emphasises explosion prevention and controlled-burn strategies, because conventional suppression has proved ineffective in many lithium-ion events. Even after apparent extinguishment, damaged cells may retain significant stored energy and can re-ignite hours or days later, requiring extended monitoring and controlled access.

3.4 Vehicle Battery Hazards (Traction Packs)

Electric heavy trucks carry large traction battery packs of several hundred kWh, typically designed to automotive functional-safety and battery-safety standards, but still subject to thermal-runaway risks from crush, penetration, internal faults, coolant leaks, or overcharge. Electric-vehicle fires may originate in the drivetrain or auxiliary systems but, once the traction pack is involved, can be prolonged, difficult to extinguish, and capable of re-ignition due to stranded energy.

The proximity of multiple electric trucks within a charge park means that a fire in one vehicle can quickly impinge on adjacent vehicles, potentially involving multiple high-energy battery packs and creating an incident far more severe than a single-vehicle fire in ordinary traffic. Charging also temporarily connects the traction battery directly to external power and communication systems, creating additional failure modes that involve both the vehicle and the EVSE.

3.5 Parking, Structural, and Environmental Hazards

Dense parking of large vehicles with minimal spacing, as observed in many urban lots, produces very high fire-load densities and rapid horizontal and vertical fire spread between vehicles. Canopies and structural elements can trap heat and smoke if not designed for venting, increasing the risk of flashover and structural damage. In addition, accumulation of combustible materials such as packaging, tyres, fuels and lubricants, among others in parking or staging areas increases fire severity.

Environmental factors such as high ambient temperatures, direct solar gain, and dust pollution can degrade equipment and accelerate insulation ageing, particularly for outdoor EVSE and cabling, thereby increasing the likelihood of electrical faults and fires over time. Flooding or water-logging in low-lying areas can challenge EVSE designed only for shallow water exposure and may cause failures on re-energisation after a flood event.

3.6 Human and Operational Hazards

Common human-factor issues include unauthorised modifications of electrical systems, bypassing of protective devices, use of non-certified chargers or adapters, improper routing of cables across circulation paths, and storage of combustible goods near electrical equipment. Lack of training leads to poor response to early warning signs such as smell, abnormal heating, repeated breaker trips. It may also result in delayed isolation of faulty equipment, and unsafe attempts to extinguish electrical or lithium-ion fires by inappropriate methods.

Contractor activity (e.g., hot work, welding, cutting, or temporary wiring) in or near the charge park can introduce ignition sources in the presence of flammable gases from the BESS or vehicles, particularly where hot-work permits and isolation procedures are not rigorously enforced. Inadequate security and access control may allow vandalism or tampering with EVSE, BESS enclosures, or electrical rooms.

Chapter 4 · Mandatory and Optional Safety Controls

4.1 Site Selection and Macro-Siting Controls

Mandatory controls include selecting sites away from high-density residential or other sensitive occupancies where feasible and ensuring compliance with NBC zoning and local land-use regulations. The site should provide adequate marginal setbacks to allow for fire-engine access around the perimeter, unobstructed approach roads, and space for separation between hazardous zones (the electrical yard, BESS yard, charging bays, and buildings).

Optional enhancements include co-locating charge parks with logistics hubs or depots where additional supervision and access control are available, integrating renewable generation (solar canopies) with appropriate fire and electrical safety, and providing redundant access roads for large-scale facilities.

4.2 Layout, Compartmentation, and Minimum Separation Distances

Key layout principles, drawn from the NBC, MoHUA parking guidelines, and BESS standards, include:

- Separating the electrical yard (11 kV equipment, transformers, main LV switchgear) from vehicle zones with non-combustible, fire-rated walls and secure fencing.
- Placing the BESS in a dedicated yard with minimum spacing between containers (for example, 6 m) and at least 10–25 m from occupied buildings, depending on energy content and mitigation measures.
- Maintaining at least 10 m separation between EV charging areas and combustible storage or vegetation, and at least 15 m from high-risk installations such as fuel tanks and transformers, in line with EV-charging and retail-outlet integration advisories.
- Providing generous spacing between heavy-truck bays beyond car-park norms, to reduce fire-spread potential and facilitate manoeuvring of fire appliances.

Where site constraints limit ideal separations, compensatory measures such as fire walls, water curtains, or enhanced detection and ventilation may be required based on a quantitative risk assessment. In India, these provisions are governed by Central Electricity Authority (CEA) safety regulations and Ministry of Power (MoP) guidelines; the sub-sections below set out the critical parking and infrastructure requirements specific to electric-truck charging.

4.2.1 Geometric and spatial requirements

Electric trucks have large turning radii and side-mounted charging ports that vary by OEMs.

- **Bay dimensions:** A standard bay for an electric truck should be at least 15–20 m long and 4.5 m wide, to allow manoeuvring and door clearance.
- **Drive-through layout:** For highway stations, drive-through bays (as at diesel fuel bunks) are mandatory; ‘Head-in’ or ‘reverse-in’ parking is difficult for long-haul trucks with trailers and often leads to cable tension or damage.
- **Turning radius:** A minimum inner turning radius of 12–15 m should be maintained for entry and exit lanes, to prevent trucks hitting charger pedestals or bollards.

4.2.2 Charger placement and cable management

High-power DC cables (MCS or dual-CCS 2) are heavy, liquid-cooled, and have limited flexibility.

- **The 5-metre rule:** As per CEA safety practice, the vehicle inlet should be within 5 m of the charging point.
- **Raised islands:** Chargers should be installed on a raised concrete island (at least 200 mm high) or protected by heavy-duty steel bollards, to prevent accidental impact from truck wheels or overhangs.
- **Height clearance:** Where the charging station is covered, canopy height should be at least 5.5 m, to accommodate high-cube containers and overhead cooling systems.

4.2.3 Compartmentation and partitions

In high-power DC charging (often exceeding 250–500 kW per truck), compartmentation is a critical passive fire-safety strategy: its goal is to prevent a thermal-runaway event in one truck from spreading to adjacent vehicles or to the main charging infrastructure. The following approach, consistent with NBC guidance and international practice, is recommended for the design of partitions and compartments in an electric-truck charging hub.

Fire-rated physical partitions

Where trucks are parked side-by-side rather than in a drive-through island, physical barriers are necessary to prevent lateral flame spread.

- **Fire-wall specification:** Install fire-rated walls between charging bays, with a minimum 2-hour (120-minute) fire-resistance rating.
- **Material:** Reinforced cement concrete (RCC) or specialised fire-rated masonry; avoid metal sheeting, which conducts heat rapidly to the adjacent bay.
- **Dimensions:** Wall height should be at least 0.5–1 m above the top of the truck (roughly at least 5 m total) to contain vertical flame plumes, and the wall should extend at least 1 m beyond the front and rear of the truck's battery-pack location.

Infrastructure compartmentation

The "power heart" (transformers and rectifiers) must be physically separated from the "charging point" where the truck is parked.

- **The 6-metre rule.** Place the high-voltage transformer and the main DC rectifier cabinets in a separate, fenced compartment at least 6 m away from the truck parking bays.
- **Trenching.** Use separate, fire-stopped cable trenches for AC input and DC output; fire-stop seals (intumescent pillows) prevent a fire in the parking bay from travelling through the cable ducts back to the main substation.

Spatial separation — the ‘Buffer’ method

Where building walls are not feasible owing to site constraints, Distance Compartmentation is used instead.

- **Isolation bay.** Designate every fourth or fifth bay as an "emergency isolation bay" that remains empty.
- **Clearance.** Maintain a minimum clear distance of 10 m between clusters of three trucks, acting as a natural break to prevent a mass conflagration.

Drainage and run-off compartmentation

- **Contained drainage.** The charging-bay floor should be sloped slightly toward a dedicated drainage pit.

- In a fire, thousands of litres of water will be used; this water becomes highly acidic and toxic. Compartmentalising the drainage ensures this 'toxic run-off' does not flow into public sewers or nearby soil but is instead captured for treatment.
- Common ceilings or continuous metal sheds should not be used over multiple truck bays without smoke curtains. Smoke curtains help compartmentalize the toxic gas and heat, allowing the sprinkler or exhaust system to work effectively in a localized zone.

4.2.4 Critical Design Distances

Table 1 provides the critical design distances recommended in this report, based on widely followed practice.

Table 1. *Critical design distances*

S.No.	Features	Requirements	Rationale
1	Inter-truck Distance	Minimum 5 m (Lateral)	Prevents radiant heat causing thermal runaway in the nearby Electric trucks.
2	Wall Height	Minimum: tallest truck height + (0.5 to 1) m	Deflects "jet flames" away from the canopy.
3	Transformer Buffer	6 meters minimum	Protects the grid infrastructure from vehicle fires
4	Drainage Slope	1:50 toward pit	Directs toxic firefighting runoff to a containment zone

4.3 Civil and Structural Controls

For a high-power DC charging hub for electric trucks in India, compartmentation is a regulatory necessity under CEA (Measures Relating to Safety and Electric Supply) requirements and the National Building Code (NBC), not merely a design preference.

4.3.1 Fire-rated material selection (Indian context)

Materials must be non-combustible and provide at least 120 minutes (2 hours) of fire resistance.

- **Bay partitions — RCC:** the gold standard for India; a 150 mm thick reinforced-concrete wall provides over 2 hours of fire rating.
- **Bay partitions — AAC blocks:** autoclaved aerated concrete blocks are lightweight with excellent thermal insulation properties, preventing a "hot wall" effect igniting a truck in the next bay.
- **Bay partitions — fire-rated vermiculite plaster:** where existing brick walls are used, a 15–25 mm coating of vermiculite-based plaster can enhance the fire rating.
- **Overhead smoke baffles — fire curtains:** automatic, deployable curtains of PU-coated fiberglass fabric drop from the ceiling when the fire alarm is triggered, trapping toxic smoke and heat within one bay.

4.3.2 Penetration sealing (fire-stopping)

The greatest risk in a DC hub is fire travelling through cable trenches from the truck bay to the transformer.

- Use **intumescent sealants** to seal every point where DC cables enter the charger pedestal or the substation, expanding up to thirty times their size when heated to choke off the fire's path.

- Use **fire-stop mortar** for large floor openings in cable rooms, creating a hard, fire-proof floor seal that supports the weight of technicians while maintaining a 3-hour fire barrier.
- Apply **intumescent cable coatings** for at least 1 metre on either side of a partition wall, preventing the cable jacket itself from acting as a "fuse" carrying fire across compartments.

4.3.3 Structural fire protection systems

Structural fire-protection methods are passive systems designed to maintain the load-bearing capacity of building materials — steel, concrete, and timber — during a fire, preventing collapse and slowing the spread. Passive fire protection will help prevent a fire from spreading or resist the initial ignition. These systems insulate the steel structures for a prescribed period of time from the effects of the high temperatures that may be generated during a fire. Two categories are used: non-reactive systems, whose insulation properties resist fire spread, and reactive systems, which swell and expand under heat to insulate structural steel.

- **Spray-applied fire-resistive material (SFRM)** consisting of Portland cement, binders, and aggregates, forms an insulating thick layer that insulates to prevent structural-steel failure under rapidly rising temperatures.
- **Fire-resistant boards:** rigid boards of calcium silicate, gypsum, or mineral wool, boxed around structural members can withstand temperatures exceeding 1,400°C and are resistant to humidity, making them suitable for long-term protection in charging zones (*see* Figure 4). Calcium silicate is a high-performing material typically classified as Class 0 or A1 non-combustible under international standards such as BS 476 or EN 13501.
- **Intumescent coatings** — epoxy-based, paint-like mixtures applied to primed steel — expand to many times their original thickness on exposure to heat, forming an insulating blanket around the structural member.



Figure 4. *A national-highway EV charging hub with fire protection boards installed between adjacent truck charging bays.*

4.3.4 Typical Fire Resistance Ratings

The fire resistance rating (FRR) is typically measured in minutes for Integrity (E), Insulation (I), and Stability/Load-bearing (R) (30, 60, 90, 120, 180 or 240). Table 2 provides a general breakdown of how board thickness correlates to fire protection for standard partitions.

Table 2. *Fire-resistance rating by board thickness (Integrity, Insulation, and Stability/load-bearing).*

S.No.	Thickness (mm)	Approx. Fire rating (min)	Common application
1	12	30–60	Basic compartmentation; aesthetic cladding with minor fire protection.
2	15–20	60–90	Standard internal partitions between smaller charging units.
3	25–30	120	Industry standard for high-voltage DC cabinets and bus charging bays.
4	40	180	High-risk zones; structural-steel protection for charging sheds.
5	50–60	240	Critical infrastructure boundaries; transformer-vault separations.

Note: *performance varies slightly by manufacturer and by whether the installation is single- or multi-layer. To achieve a 240-minute rating, installers often use a "staggered joint" method with two layers of thinner boards rather than one ultra-thick board.*

4.4 Electrical Design and Installation Controls

Electrical safety controls, derived from CEA regulations, IS 17017, and IS 3043, include:

- Correct equipment ratings and insulation coordination for fault levels and environmental conditions, with clear labelling and phase identification.
- A comprehensive earthing and bonding network as per IS 3043, with low-impedance fault paths and multiple connections for MV equipment, integrated with lightning protection as per IS/IEC 62305 and thunderstorm arresters.
- Overcurrent, short-circuit, earth-fault, and residual-current protections coordinated from the HV intake through LV distribution to individual chargers, with appropriate discrimination to avoid unnecessary outages; residual-current devices to cut off power in the event of dangerous DC leakage (typically above 6 mA DC).
- Use of high-integrity EV charging cables (for example, to IEC 62893-1), for critical circuits, routed away from gas lines, other services, and fire-exit paths.
- Arc-fault detection devices and surge-protection devices on EVSE feeders and panels, to mitigate arc-induced fires and transient overvoltage damage.
- Insulation-monitoring devices for detecting insulation degradation by detecting leakage currents as per IEC 61557-8 standard; the electric-bridge-switch method monitors insulation resistance between HV DC components and protective earth while charging is in progress.
- Galvanically isolated amplifiers and switches (for example, TPSI2140-class devices) are used to isolate measurement circuits on the hot side, ensuring safety while enabling monitoring from the cold side.

- EMI shielding such as aluminium foil or braided conductive fabrics is used to block electromagnetic interference (EMI) that could disrupt communication between the truck and the charger.

4.5 EVSE Design and Installation Controls

- Install EVSE at heights above likely flood levels (for example, 800 mm above the flood line for certain installations) and protect against water ingress.
- Provide mechanical protection (bollards, kerbs) to protect chargers, cable terminations, and distribution boards from vehicle impact.
- Avoid routing power cables alongside other service pipes (gas, water) or through escape routes.
- Locate charging bays outside hazardous zones — for example, at least 15 m away from fuel dispensers or underground tanks if located at a petrol pump or retail outlet.
- For indoor or basement truck depots, provide mandatory mechanical ventilation to disperse heat and any gas release during high-speed (240 kW+) charging.

4.6 BESS-Specific Controls

For charge parks with an on-site BESS, controls based on NFPA 855 and established engineering practice include:

- Container design with fire-resistant construction, internal detection and suppression where used, and engineered ventilation and deflagration venting to prevent overpressure.
- Minimum spacing between containers (for example, 6 m) and separation distances from occupied buildings (for example, 25 m), unless mitigated by fire-resistant barriers or a performance-based design.
- Dedicated, monitored gas detection for flammable gases and toxic species where relevant, interfaced with the site fire-alarm and emergency-shutdown systems.
- Battery-management and power-conversion systems with multi-level protection: cell/module voltage and temperature monitoring, current limits, state-of-charge management, and emergency-shutdown logic.
- A clear emergency-response plan that allows a controlled burn where suppression is ineffective, manages run-off, and provides for post-incident monitoring against re-ignition.

4.7 Markings, Signage, and Information Systems

Mandatory markings include hazard signage ("Danger – High Voltage", "Battery Energy Storage – Explosion/Fire Risk"), directional signs to exits and assembly points, and clear bay demarcation ("EV Charging Only", "No Parking – Keep Clear"). EV-charging safety SOPs and pictorial warnings should be displayed near each charger — for example, "Switch off vehicle while charging", "Do not smoke", and "Report damage immediately" (*see* Figure 5).



Figure 5. *Various safety signs for Charging infrastructure.*

For BESS and electrical rooms, information boards should show single-line diagrams, key isolation points, emergency-shutdown procedures, and contact details for responsible persons and utility control centres. Signage should comply with the NBC and local fire-service requirements for visibility and durability.

Operational signage and markings

- **Distinct markings:** Use thermoplastic green paint for the entire bay surface, with a large "EV" logo.
- **Enforcement:** Clearly signpost the area as "EV Trucks Only", to prevent internal-combustion-engine vehicles from blocking truck-bay entry.
- **Emergency lane:** Always maintain a clear, unobstructed path for emergency vehicles such as fire tenders to access the truck in the event of a battery thermal event.

Chapter 5 · Fire Detection, Alarm, and Suppression Systems

5.1 Detection Technologies and Zoning

- An addressable fire-detection system using smoke (photoelectric type) and/or heat detectors (bi-metallic type, heat-sensitive cables, or thermistor-based detectors), or flame detectors (ultraviolet, infrared, or combined UV-IR) (*see* Figure 6), in buildings, switch rooms, and cable basements, with aspirating or early-warning detection in critical rooms such as control rooms and BESS containers.
- Manual call points and sounders/beacons across the site, integrated with EVSE and BESS control systems to trigger safe shutdown and isolation in a fire event.

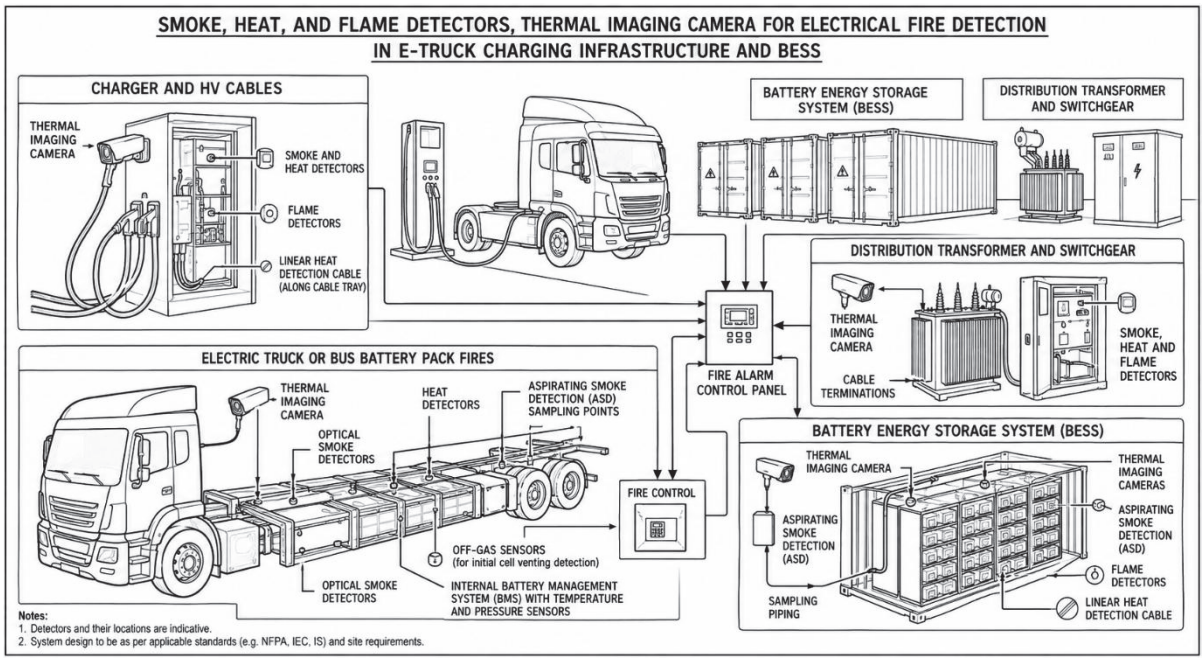


Figure 6. *Various Fire detection systems in Charging infrastructure*

5.2 Fixed Suppression for Electrical and Structural Fires

A site fire-hydrant system with static water storage and pumps sized as per NBC Part 4 and local fire-NOC requirements, with hydrants strategically located around the electrical yard, BESS yard, and vehicle zones, is required. Four categories of fixed fire suppression system are relevant to charge parks (*see* Figure 7):

- Clean-agent gas systems (Novec 1230, FM-200) for total flooding of electrical control rooms and battery-storage enclosures — no residue, non-conductive.
- Water-based systems (automatic sprinklers, water mist) for the charging-bay area, providing cooling and fire suppression in open areas and on vehicles.
- Aerosol suppression systems (Stat-X, FirePro) for localised protection within DC fast-charger cabinets and enclosed spaces, offering rapid response without piping.
- Inert-gas systems (N_2, IG-541, IG-100) for total flooding of BESS containers to displace oxygen, environmentally friendly and residue-free.

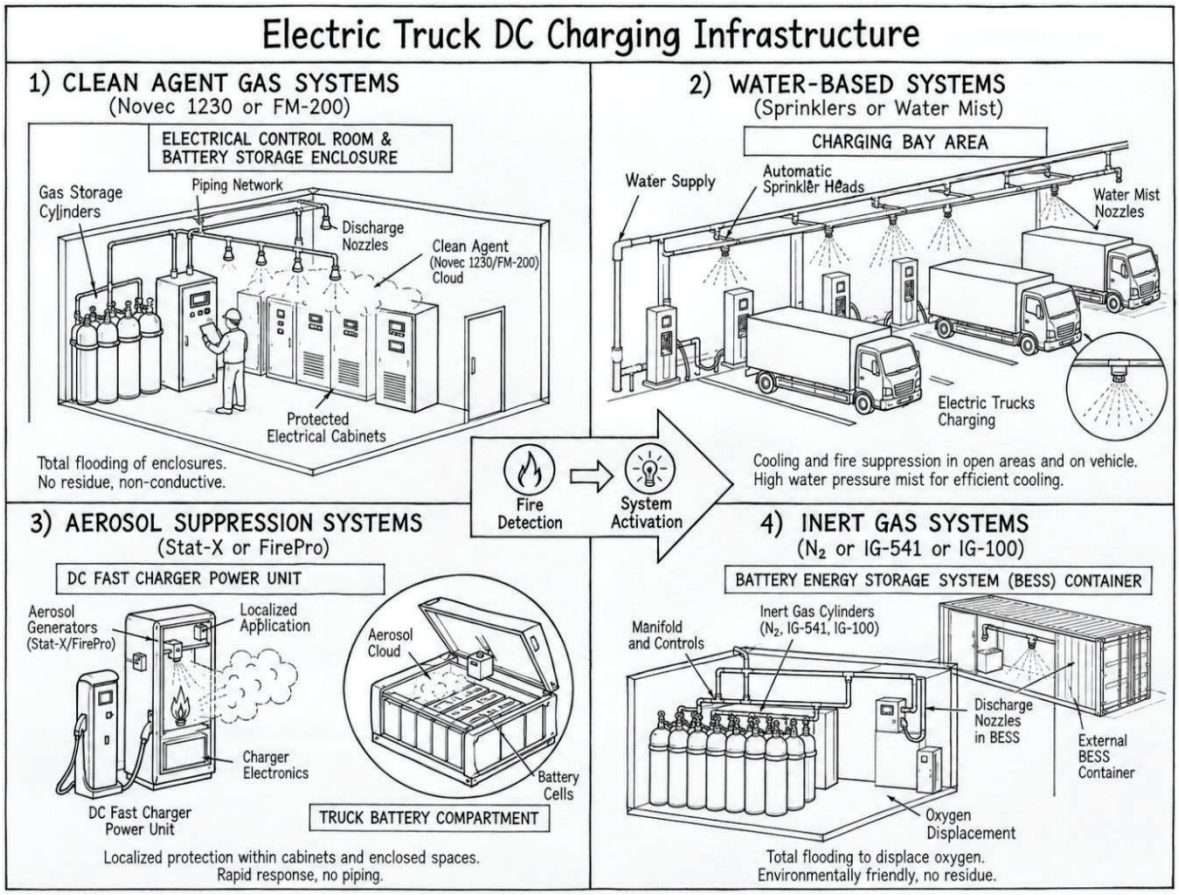


Figure 7. *Four classes of fixed fire-suppression systems used in DC charging infrastructures.*

Sprinkler design requirements

For indoor or enclosed battery systems up to 60 kWh, NFPA 855 requires:

- Design density of at least 12.2 litres/minute/m².
- Density applied over a minimum area of 230 m², or the entire space, whichever is smaller.
- Water supply capable of providing this flow for at least 90 minutes.
- Portable CO_2 and ABC/DCP fire extinguishers for electrical and ordinary combustibles, positioned near EVSE, electrical rooms, and control rooms as required by safety advisories.
- Where feasible, water-mist systems or monitors for vehicle and canopy fires, with strict procedures to avoid direct application of water onto energised HV equipment.

5.3 Specialised Approaches for EV and BESS Fires

For EV and BESS lithium-ion fires specifically, emerging best practice is to focus on cooling and containment rather than complete extinguishment, potentially using high-flow water application from a safe distance, encapsulating agents, or fire blankets for small battery modules, while coordinating closely with the fire brigade.

For small electrical fires involving lithium-ion battery packs, Aqueous Vermiculite Dispersion (AVD), a magnesium-aluminium-iron silicate mineral suspended in water, or Hydrated Mica Suspension (HMS), a hydrated potassium aluminium silicate dispersed with sodium polyacrylate may be used (*see* Table 3). On discharge, the AVD/HMS

agent forms a fine mist that cools the heat source and coats it in a protective barrier, quickly stopping flame spread and significantly reducing the risk of re-ignition.

Table 3. *Fire extinguisher selection for DC charging infrastructure.*

Fire location	Extinguisher NOT to be used	Extinguisher TO be used
Electrical components (transformer, charger, HT cables).		
Battery Energy Storage Systems (Li-ion) and battery packs from electric trucks or buses.		

Newer fire extinguishing agents such as perfluorohexanone and hydrogels for lithium-ion battery fires can effectively suppress flames and prevent fire propagation and re-ignition at high temperatures; AF-31 (marketed as AF-31 EV) is a water-based extinguishing agent engineered specifically for lithium-ion battery fires. Re-ignition occurs because the chemical reaction inside the lithium battery has not fully stopped, which makes it difficult to extinguish the fire completely with the conventional fire extinguishers.

For a high-intensity battery-pack lithium-ion fire, emergency responders often report needing between 11,000 and 30,000 litres of salt-free water to fully cool an EV battery and prevent re-ignition; in extreme cases, 11,000 to 1,15,000 litres of salt-free water may be required over four hours to permanently suppress an electric truck or bus battery fire. NFPA does not set a single 'required' quantity for any individual vehicle fire. Specialised battery thermal-runaway suppressants, such as a 3% solution of F-500 encapsulating agent in water (Figure 8), are recommended for BESS or battery pack fires in electric trucks.

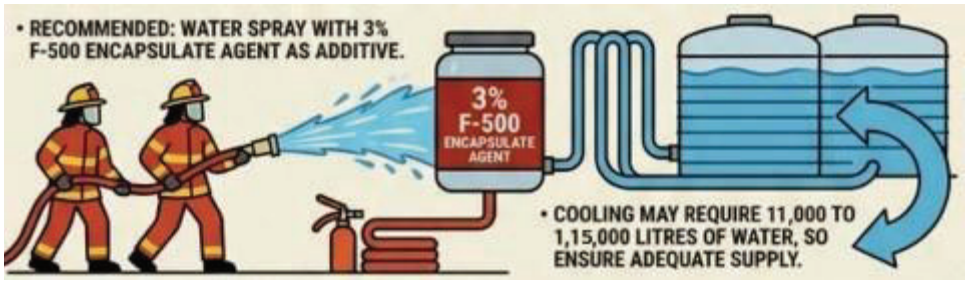


Figure 8. *Hydrants Requirement in DC Charging infrastructure for Electric Trucks or Buses.*

Fire blankets

Fire blankets are used for small electrical fires at a charging station or battery fires in electric trucks or buses. Four types of fire blankets are commercially available (*see* Figure 9):

- **Silicone-coated Fibreglass —** early fire containment for 5–10 minutes at temperatures up to 260°C.
- **Silicone-coated Silica —** resists sustained temperatures above 900°C for 10–20 minutes.

- **Graphite-coated Silica —** withstands flame temperatures of 1,000–1,500°C for 2–5 minutes.
- **Vermiculite-coated Silica —** superior fire resistance at temperatures of 1,000–1,200°C.

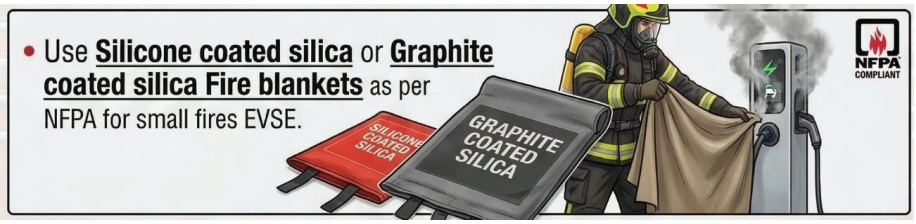


Figure 9. *Fire Blankets to be used in an Electric Vehicle DC Charging infrastructure.*

An indicative list of manufacturers of fire extinguishers, suppression systems, and fire blankets is provided at **Appendix 2**.

5.4 Utilities and Water Supply Planning

Given the severity of thermal-runaway risk in heavy-duty EV batteries, specialised fire-suppression infrastructure is critical.

- **Hydrant layout and static tanks:** Hydrants must be strategically positioned for 360-degree firefighting access, ensuring hoses never cross high-voltage pathways. Because municipal water grids often lack the sustained flow rates required for EV fires, high-capacity underground static water tanks are mandatory to support prolonged suppression. Water tanks should be equipped with dual, independent pumping systems (for example, one electric, one diesel-driven) to maintain pressure during grid outages caused by the fire itself.
- **Sprinkler design:** Charging canopies should integrate automated deluge sprinkler systems, triggered by advanced thermal sensors, to provide immediate ambient cooling and prevent fire propagation to adjacent charging bays.
- **Water removal:** Post-suppression run-off is highly toxic. Site grading must channel this contaminated water into sealed, subterranean containment basins equipped with heavy-metal filtration, preventing groundwater contamination prior to safe hazardous-waste disposal. Retained firewater is classified as hazardous waste, and the facility plan must include standardised access points for vacuum trucks to safely pump out and transport the contaminated water to specialised chemical-treatment facilities.

5.5 Interface with First Responders and External Agencies

Effective interfacing with first responders is critical for mitigating fire hazards at dual-gun DC high-power charging stations for electric trucks and buses. Given the severe thermal-runaway risks inherent to heavy-duty commercial vehicle battery packs, stations must maintain automated, real-time telemetry links with local fire-control rooms, instantly sharing temperature anomalies and active charging status.

Protocols must mandate remote Emergency Power-Off (EPO) switches accessible to emergency personnel for immediate high-voltage isolation. Seamless coordination with state grid operators and local nodal agencies is essential to establish secure perimeters, manage heavy-vehicle traffic, and execute specialised EV fire-suppression tactics safely.

Chapter 6 · Emergency Management

6.1 Emergency Response Plans

A charge park's emergency response plan must address fire, electric shock, spill, structural damage, and grid outage as related but distinct scenarios, coordinated through a single, rehearsed procedure covering alert and alarm, power isolation, notification of external services, safe evacuation, assembly, access restriction, and first aid. Figure 10 provides the instructions for all staff, drivers and visitors of charging stations during fire incidents.



Figure 10. *Fire incident procedure for site staff, electric-truck drivers, and visitors.*

6.2 Fire Rescue Techniques for the Charger

Figure 11 provides the fire rescue sequence for a charging station involving electric truck or bus.

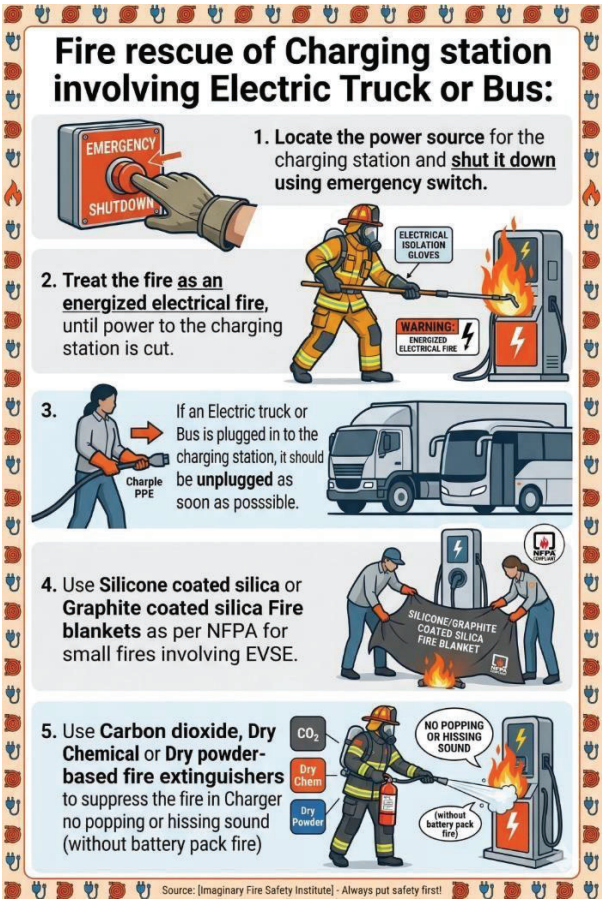


Figure 11. *Fire rescue sequence for a charging station involving an electric truck or bus*

6.3 Post-Incident Management

Re-energisation criteria, forensic investigation, and lessons-learned review are as safety-critical as the initial response. Figure 12 provides some important instructions related to post-incident safety.



Figure 12. *Post-incident safety priorities.*

6.4 Fire Rescue Techniques for Electric Trucks

Figure 13 provides the fire rescue procedure for a parked or charging electric truck involving a battery-pack fire covering initial scene safety and awareness; extinguishment methods for small versus large lithium-ion battery fires; high-voltage hazards; and post-fire management procedures.



Figure 13. *Fire rescue of a parked or charging electric truck involving a battery-pack fire*

Chapter 7 · Roles, Training, and Skilling Requirements

7.1 Competency and Training Matrix

Training requirements shall include the following:

- **Electrical safety and regulations:** for O&M staff and supervisors, covering CEA safety regulations, earthing, lock-out/tag-out (LOTO), and arc-flash awareness.
- **EV charging operations:** for charging-point operators and security staff, including charger start/stop procedures, recognising fault conditions, isolation steps, and user assistance.
- **Battery and BESS hazards:** for O&M staff, operators, and local fire services, covering thermal runaway, gas hazards, re-ignition, and appropriate firefighting tactics.
- **Fire-fighting equipment use:** for all on-site staff, with hands-on practice using portable extinguishers, hydrants, and hose reels as applicable.
- **Emergency response and evacuation:** for all staff and, periodically, for drivers, through signage, leaflets, or briefings focused on alarm recognition, muster points, and avoiding re-entry.

National and state-level training programmes on electrical safety, lithium-ion battery risk, and industrial fire safety — including courses offered by government agencies and accredited bodies — can be leveraged to build capacity, supplemented by charge-park-specific training modules covering site layouts, specific equipment, and SOPs.

7.2 Frequency and Assessment

Initial induction training must be provided before staff assume duties, followed by periodic refresher training, typically annually or as mandated by local regulations. Fire and evacuation drills should be conducted at least once a year (preferably twice), including coordination with local fire services where possible.

Competency should be assessed through written tests, practical demonstrations (for example, use of extinguishers), and evaluation during drills, with records maintained as part of the site's safety-management system.

Chapter 8 · Checklists, Do's and Don'ts, and Model SOPs

Implementing a high-powered DC charging station — typically 240 kW to 1.5 MW for electric trucks and buses in the Indian context — requires careful planning, adherence to strict regulatory standards, and robust operational protocols, given the high electrical loads and safety risks involved.

8.1 Design and Approval Phase Checklist (Indicative)

- Compliance with NBC Part 4 and local building bye-laws for fire safety and egress.
- Compliance with MoP EV-charging-infrastructure guidelines and minimum heavy-duty charging infrastructure requirements (for example, 240 kW chargers for MD/HD vehicles).
- Application of CEA safety regulations for HV/LV systems, including clearances, earthing, and protection.
- Use of BIS EV-charging standards (IS 17017 series, IS 15118) for charger specifications and interoperability.
- Dedicated zoning and separation distances for the electrical yard, BESS, charging bays, parking, and buildings, aligned with NFPA 855 concepts where a BESS is present.
- Adequate hydrant, water storage, and fire detection and alarm systems sized for the site, with a fire NOC obtained as required.

8.2 Do's and Don'ts

Site planning and safety

High-powered DC charging stations are commercial hubs with high traffic and serious electrical risks. Table 4 gives a list of Do's and Don'ts related to site planning and safety.

Table 4. *Site planning and safety — Do's and Don'ts.*

S.No.	Aspect	Do's	Don'ts
1	Site selection	**DO** prioritise high-traffic, accessible, and visible locations like highways (every 25 km on both sides), malls, corporate parks, or petrol pumps. Conduct a proper traffic-flow analysis.	**DON'T** tuck the station away in a remote or hard-to-access area. Visibility and convenience are the primary drivers of charger utilisation.
2	Civil and space	**DO** provide adequate space for simultaneous charging, clear entry/exit points, and wide parking bays to prevent vehicle damage and cable stretching. Protect chargers with kerbs, bollards, or metal barriers.	**DON'T** cram chargers into small spots where vehicles struggle to manoeuvre. Heavy DC cables must reach the vehicle inlet without tension.
3	Wet conditions	**DO** ensure adequate drainage at the charging stations and protect all electrical components from water ingress. The installation must be designed to withstand heavy rainfall.	**DON'T** operate the station if the area is flooded or if charging-gun connectors are visibly wet. High voltage electricity and water together create a severe shock hazard.

S.No.	Aspect	Do's	Don'ts
4	Fire protection	**DO** install adequate fire-protection equipment and facilities like specialised extinguishers for electrical/lithium fires as per relevant Indian standards.	**DON'T** store flammable fluids or hazardous materials within the designated charging area. Enclosures should be fire-retardant.
5	Accessibility	**DO** install the supply socket-outlet at least 800 mm above the highest flood level of the area.	**DON'T** stretch the charging cable over 5 m to reach a vehicle. Cable length should be sufficient but contained within the bay.

EV user etiquette (public charging stations)

Table 5 gives a list of Do's and Don'ts related to EV user etiquette at the public charging stations.

Table 5. *EV user etiquette (at public charging stations) — Do's and Don'ts.*

S.No.	Aspect	Do's	Don'ts
1	Check availability	**DO** educate users to check real-time availability and connector status via apps (Tata Power EZ Charge, Incharz, Statiq, and similar) before arriving.	**DON'T** let users block charging bays if they are not genuinely charging. Parking in charging spots is a severe issue in crowded Indian urban areas.
2	Move after charge	**DO** educate users to unplug and vacate the bay immediately after charging completes or reaches their desired state of charge (usually 80%).	**DON'T** allow users to treat charging stations as long-term parking, which blocks fast chargers from long-distance drivers.
3	Use emergency stop	**DO** have a clearly marked emergency button. Educate users to press it only in case of fire, smoke, or a visible hazard.	**DON'T** use the emergency stop button to end a normal charging session. Users should use the app or the charger's standard "Stop" procedure.
4	Child safety	**DO** make the station as child-proof as possible and preferably install it away from children's play areas.	**DON'T** allow children to operate high-powered DC charging equipment.
5	Cleanliness	**DO** keep the bay area clean and tidy. Ensure users place the heavy DC gun back in its holder properly after use.	**DON'T** touch any live wire with bare hands or tamper with the equipment internals.

8.3 SOP Concepts for Key Scenarios

Model SOPs to be developed for a charge park should cover, at minimum:

- **Normal start-up and shutdown of charging operations —** steps for energising equipment after maintenance, checking protections, enabling EVSE, and coordinating with the utility.
- **Response to EVSE fault or minor electrical fire —** isolation procedures, use of appropriate extinguishers, notification cascade, and safe re-energisation criteria.
- **EV traction-battery fire in a truck bay —** immediate alarm, isolation of chargers, evacuation, establishment of an exclusion zone, controlled water application per fire-brigade guidance, monitoring for re-ignition, and coordination with the fleet owner and authorities.

- **BESS incident —** BESS-specific alarm response, container isolation, gas monitoring, a controlled-burn strategy where indicated, and re-entry protocols in line with NFPA 855 and OEM guidance.

8.4 First Aid Procedure

Figure 14 provides the first aid procedure for electric-truck charging-station fire hazards, covering electrical shock, chemical/toxic smoke inhalation, and thermal burns.



Figure 14. *First aid for electric-truck charging-station fire hazards*

References

1. Central Electricity Authority (CEA). Measures Relating to Safety and Electric Supply Regulations.
2. Central Electricity Authority (CEA) and Ministry of Power (MoP). Guidelines for Installation of Public Electric Vehicle Charging Infrastructure.
3. Bureau of Indian Standards. National Building Code of India (NBC), Part 4 — Fire and Life Safety.
4. National Fire Protection Association. NFPA 855, Standard for the Installation of Stationary Energy Storage Systems.
5. Bureau of Indian Standards. IS 3043, Code of Practice for Earthing.
6. Bureau of Indian Standards / International Electrotechnical Commission. IS/IEC 62305, Protection Against Lightning.
7. Bureau of Indian Standards. IS 17017 (Part 23 / Part 30), Electric Vehicle Conductive Charging System — DC EV Supply Equipment.
8. International Organization for Standardization / Bureau of Indian Standards. ISO 15118 / IS 15118, Road Vehicles — Vehicle-to-Grid Communication Interface.
9. International Electrotechnical Commission. IEC 61557-8, Insulation Monitoring Devices for IT Systems.
10. International Electrotechnical Commission. IEC 62893-1, Charging cables for electric vehicles for rated voltages up to and including 0,6/1 kV - Part 1: General requirements.
11. Petroleum and Natural Gas Regulatory Board (PNGRB). Safety Standards for Retail Outlets and Fuel Stations.
12. Maharashtra Fire Services and other state fire authorities. Parking Fire Safety Guidelines, including provisions for electric-vehicle charging.
13. Ministry of Housing and Urban Affairs (MoHUA). Model Building Bye-Laws and Urban and Regional Development Plans Formulation and Implementation (URDPFI) parking guidelines.
14. British Standards Institution / European Committee for Standardization. BS 476 and EN 13501, Fire Classification of Construction Products and Building Elements.

Appendix 1 · Major Zero-Emission Trucks Currently Operating in India

Table A1 below gives an indicative list of the major zero-emission trucks (battery electric trucks/vehicles) available in India at the time of writing this report, together with vehicle dimensions, battery-pack capacity and battery chemistry, charging protocol, and rated range. Specifications should be verified against current OEM literature before use in design calculations, as battery capacity, range, and charger compatibility are updated frequently.

Table A1. *List of major zero-emission trucks available in India*

S. No.	Truck category	Vehicle Name	Vehicle Image	Vehicle Dimensions (mm)	Battery Capacity (kWh)	Charger Used	Range (km)
1	12-Ton Truck	Tata Ultra E.12		Length: 6096 Wheelbase: 4530	96 to 147 Lithium Iron Phosphate (LFP)	CCS 2 DC Fast charging	200 or 220
2	14-Ton Truck	Ashok Leyland Boss 14T EV Truck		Length: 9480 Wheelbase: 5200	201.5 Lithium Iron Phosphate (LFP)	CCS 2 DC Fast charging	230
3	19-Ton Truck	Ashok Leyland Boss 19T EV Truck		Length: 9480 Wheelbase: 5200	201.5 Lithium Iron Phosphate (LFP)	CCS 2 DC Fast charging	194
4	28-Ton Truck	Tata Prima E.28K		Length: 6800 Wheelbase: 4570	453 Lithium Iron Phosphate (LFP)	CCS 2 DC Fast charging	220
5	28-Ton Truck	Olectra Meghaetron 28T EV		Length: 8770 Wheelbase: 4975	255 Lithium Iron Phosphate (LFP)	CCS 2 180 kW DC fast charging Dual gun	150
6	55-Ton Truck	Ashok Leyland AVTR 55T EV Truck		Length: 6150 Wheelbase: 3700	302.5 Lithium Iron Phosphate (LFP)	CCS 2 DC fast charging Dual gun	180
7	55-Ton Truck	Propel EV - 4x2 470eTR		Length: 6225 Wheelbase: 3850	385 or 480 or 550 Lithium ion Nickel Manganese Cobalt (NMC)	CCS 2 DC fast charging Dual gun	350 (from 550 kWh pack)

S. No.	Truck category	Vehicle Name	Vehicle Image	Vehicle Dimensions (mm)	Battery Capacity (kWh)	Charger Used	Range (km)
8	55-Ton Truck	TATA PRIMA E.55S 4X2 TRACTOR		Length: 6550 Wheelbase: 4100	300 or 450 Lithium Iron Phosphate (LFP)	CCS 2 DC fast charging Dual gun	180 or 220
9	55-Ton Truck	Montra RHINO 5538 EV 4x2 Tractor		Length: 12000 Wheelbase: 4000	282 Lithium Iron Phosphate (LFP)	CCS 2 DC fast charging Dual gun	198
10	55-Ton Truck	Montra RHINO 5538 EV 6x4 Tractor		Length: 12000 Wheelbase: 4000	282 Lithium Iron Phosphate (LFP)	CCS 2 DC fast charging Dual gun	169
11	55-Ton Truck	EKA 55T 6x4 and 4x2		Length: 7115 Wheelbase: 4100	282 or 424 Lithium Iron Phosphate (LFP)	CCS 2 DC fast charging Dual gun	200
12	55-Ton Truck	Blue Energy Motors 5548e EV		Length: 6550 Wheelbase: 4200	282 Lithium Iron Phosphate (LFP)	Swappable - module to bracket	200
13	55-Ton Truck	Energy In Motion Ashwa		Length: 6665 Wheelbase: 3600	282 Lithium Iron Phosphate (LFP)	Dual-gun fast charging (CCS 2) and Battery Swapping	200
14	55-Ton Truck	iBoard Long haulage TT 5520		Length: 12000 Wheelbase: 7000	322 Lithium Iron Phosphate (LFP) with Refrigerant cooling	DC Fast charging CCS 2	150

Appendix 2 · Indicative List of Manufacturers / Suppliers

The following lists are **indicative and non-exhaustive**, intended to provide information to help developers and operators identify categories of suppliers active in the Indian market. Inclusion does not constitute an endorsement, and exclusion does not imply unsuitability; project teams should perform their own due diligence and specification checks against the standards mentioned in this report.

Charging-infrastructure extinguishers for electrical fire (excluding lithium-ion battery pack fires)

S.No.	Manufacturers
1	Kanex Fire Solutions Ltd.
2	United Fire Equipment Pvt. Ltd.
3	Ceasefire Industries Pvt. Ltd.
4	Safepro Fire Services Pvt. Ltd.
5	NewAge Fire Protection Industries Pvt. Ltd.
6	Safex Fire Services Ltd.
7	Mollimax Fire Protection Industries Pvt. Ltd.
8	Foamtech Antifire Company
9	Vintex Fire Protection Pvt. Ltd.
10	Impact Fire & Safety Appliances Pvt. Ltd.

Charging-infrastructure extinguishers for lithium-ion battery-pack fire

S.No.	Manufacturers
1	Bharati Fire Engineers (FIREFITE LITHEX lithium-ion battery-fire extinguisher)
2	United Fire Equipment Pvt. Ltd.
3	Kanex Fire Solutions Ltd.
4	Ceasefire Industries Pvt. Ltd.
5	Safex Fire Services Ltd.
6	Firetech Hazard Control Technologies India Pvt. Ltd.
7	Supremex Fire

Charging-infrastructure fire-suppression-system manufacturers

S.No.	Manufacturers
1	Firetech Equipment and Systems Pvt. Ltd.

S.No.	Manufacturers
2	Kanex Fire Solutions Ltd.
3	Fire Engineering Technology
4	United Fire Equipment Pvt. Ltd.
5	Axis Fire Protection
6	Fire Guards (Fire Trace System)

Charging Infrastructure - Battery Energy Storage System (BESS) manufacturers

S.No.	Manufacturer
1	Replus Engitech
2	Waaree Energies
3	Cummins India
4	Ornate Solar
5	Delta Electronics India
6	Narada Power
7	Sunwoda Energy

Charging Infrastructure - Fire-blanket manufacturers

S.No.	Manufacturer
1	HI care Protective Wear / HI care Safety Solutions (Mumbai)
2	RNG Performance Materials (Gujarat)
3	Darshan Safety Zone (Rajasthan)

Fire-protection Calcium Silicate board manufacturers

S.No.	Manufacturer
1	Wedge Industries Limited
2	Promat Fire and Insulation Pvt Ltd
3	Ramco Industries Limited
4	B.M. Enterprises

Appendix 3 · Fire Order Site Poster

The poster below is intended for display at charge-park entrances, control rooms, and charging bays, summarising the site fire order for staff, drivers, and visitors (*see* Figure 15).



Figure 15. *Fire order: prevention, protection, and extinguishment – Site Poster*

1. On closing for the day, check that all electrical connections are switched off, and familiarise yourself with the method(s) of operating the fire extinguishers provided.

2. In case of an electrical fire, use the emergency switch to shut down incoming power, and try to extinguish the fire using the nearby fire extinguisher while wearing appropriate Personal Protective Equipment (PPE).

3. Operate from a safe distance; do not approach any electric truck noticed with smoke, or a hissing or popping sound. Pull the hose reel from the nearest hydrant box and, keeping a safe distance, direct the water jet to the seat of the fire, and use proper personal protective equipment.

4. If the fire is beyond control, follow instructions given through the public-address system and escape through the nearest emergency exit, giving preference to differently-abled persons, women, the elderly, and children.

5. Remember that in the event of a fire, every second counts. Assemble at the designated assembly point and always know the nearest fire-station and emergency-hospital numbers (Fire Control Room: 101). Re-enter the charging station only after receiving clear instructions.

Acknowledgements

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